IBW Project
Verification Rationale

$$Risk = f \begin{cases} \textbf{\textit{Hazard Character}} & \begin{cases} \textit{Likelihood of Occurrence} \\ \boxed{\textit{Expected Magnitude/Intensity}} \end{cases} \\ \\ \textbf{\textit{Exposure}} & \begin{cases} \textit{Projected Time of Occurrence} \\ \textit{Projected Location of Occurrence} \end{cases} \\ \\ \textbf{\textit{Vulnerability}} & \begin{cases} \textit{Propensity of those exposed to} \\ \textit{suffer adverse impacts (indoor vs.} \\ \textit{outdoor; mobile home vs.} \\ \textit{underground shelter, etc.)} \end{cases} \end{cases}$$
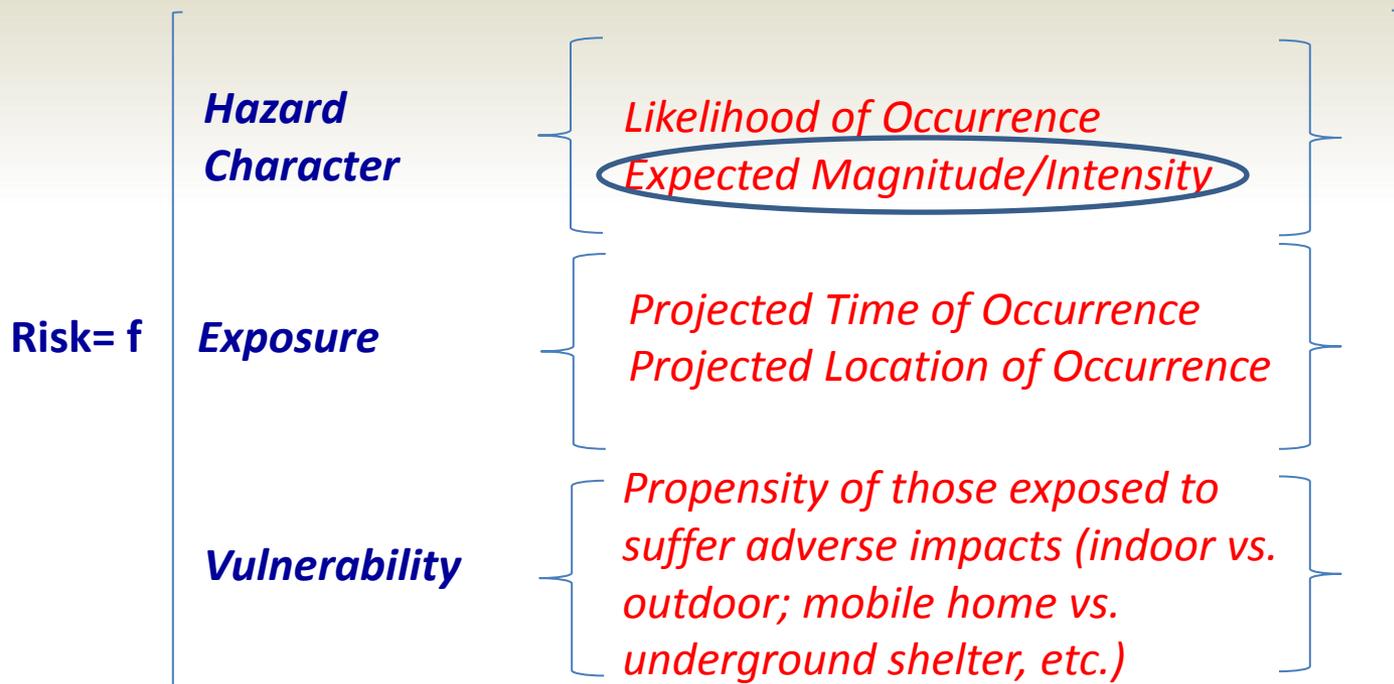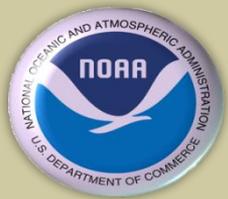
IBW is an attempt to better communicate risk, and the purpose of this evaluation is to determine if we can adequately express tornado magnitude as part of that process.

The vast majority of tornado fatalities result from EF2-5 tornadoes, and "societal needs" demand tornado warnings that emphasize these high risk/high impact events while minimizing false alarms.

The IBW method of conveying predicted tornado magnitude/intensity is the use of the Damage Threat Indicator Tags at the bottom of TOR/SVS texts. All IBW offices included except ONE.

Two Warning Tiers are evaluated; 1) Base Tier and 2) Elevated Tier. Due to an extremely small number of IBW Catastrophic tags used, Considerable and Catastrophic tags are grouped together into one tier (Elevated Tier). Observed and RADAR Indicated Tags are Base Tier Warnings.
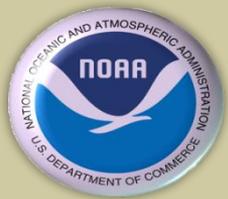
Tiers of observed tornado intensity are consistent with classifications of weak, strong , and violent tornadoes. Base Tier tornadoes are classified EF0-1. Elevated Tier tornadoes are classified as EF2-5.

The EF Scale is the industry standard for relating Damage Indicators (i.e. Impacts) to tornado magnitude. Known limitations of the EF-Scale are not accounted for in this evaluation.

Only one tornado is allowed to verify an IBW warning (no double counting). The highest EF-scale surveyed is assigned to the tornado event. All unwarned tornadoes are classified as missed events.

Lead time is not considered. SVS and TOR actions that change a warning attribute (e.g. Base Tier to Elevated Tier) are considered new warnings.

TORs and SVSs were collected via IEMCOW. Ground truth was gathered through NWS Verification Database, NWS Damage Assessment Tool database, and local WFO web pages.
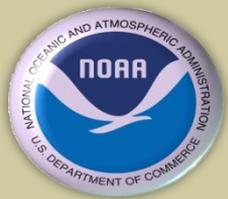
- Base Tier Warnings are dominated by false alarms (69% or worse).

- EF0-1 tornado events are marked by unwarned events (53%) – or more precisely, by unwarned EF0 tornadoes (which outnumber unwarned EF1 events by a factor of 2).

- Elevated Tier Warnings are marked by tornado occurrence (67%), with a plurality being EF2-5 tornadoes (46%) and a majority (60%) being EF1-5 tornadoes.

- Very few EF2-5 tornadoes are unwarned (10%). Of those that are warned, the majority are covered by Base Tier Warnings – suggesting the Elevated Tier Warning for larger tornadoes is under-utilized by forecasters.

- Within the IBW framework, there is skill distinguishing strong tornadoes from small/no tornadoes, especially when you factor near misses into the equation. These results are supported by findings in Smith et al. (2015) using a relational climatology comparing max low level Vrot to maximum EF-Scale tornado damage.

- The IBW warning framework appears to have value above that provided by the legacy warning system in terms of providing a basis for communicating elevated risk ….while limiting false alarms for high end tornadoes.

IBW Project
2012-2014 Verification

1741 = Total Number of Tornado Warnings

1040 = Total Number of Tornado Events

137 = Total Number of EF2-5 Tornado Events (13.5% of all tornadoes)

85 = Total Number of Elevated Tier Warnings (4.9% of all Tornado Warnings)

39 = Total Number of Elevated Warnings Verified by EF2-5 tornado

904 = Total Number of EF0-1 Tornado Events (86.5% of all tornadoes)

1656 = Total Number of Base Tier (EF0-1) Warnings (95.1% of all Tornado Warnings)

428 = Total Number of Base Tier Warnings Verified by EF0-1 tornado

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Finding: The sample sizes of both EF2-5 Tornado Events and Elevated Tier Tornado Warnings are small – and are not statistically significant.

Finding: Forecasters are conservative with their use of Elevated Damage Threat Indicators in Tornado Warnings – as indicated by the difference between EF2-5 occurrence and the use of Elevated Damage Threat Indicators in warnings.

Baseline Summary and Metrics for ALL Warnings/Events (regardless of Warning Tier)

55% = POD (Probably of Detection) for all Tornado Events
67% = FAR (False Alarm Rate) for all Tornado Warnings
33% = Hit Rate for all Tornado Warnings (1-FAR)
0.26 = Critical Success Index

Finding: Despite slightly different methodology, overall statistics from the IBW database are similar to statistics in the National Verification Database. This, in a general sense, confirms the data validity contained within the IBW database.

| Warning/Observed	No Tornado	Tornado
No Warning	None	Missed Event
Warning	False Alarm	Hit
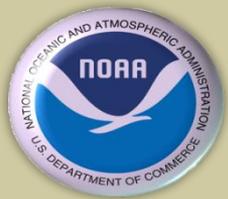
IBW Project
2012-2014 Verification

Warning/Observed	No Tornado	EF0-1	EF2-5
No Warning	None (a)	Base Missed Event (b)	Elevated Missed Event (c)
Base Tier Warnings	Base Tier False Alarm (d)	Base Category Hit (e)	EF3+ Base Category Miss (f) EF2 Base Near Miss (j)
Elevated Tier Warning	Elevated False Alarm (g)	EF0 Elevated Category Miss (h) EF1 Elevated Near Miss (k)	Elevated Category Hit (i)
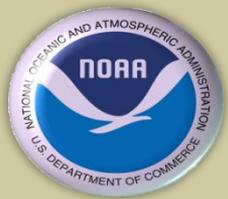
$PCD_1 = \dfrac{\text{(\# EF2-5 Tornadoes Warned in Elevated Tier)} + \alpha(\text{\# EF2-5 Tornadoes Warned in Base Tier)}}{\text{(\# EF2-5 Tornadoes)}}$

$PCD_2 = \dfrac{\text{(\# EF0-1 Tornadoes Warned in Base Tier)} + \beta(\text{\# EF0-1 Tornadoes Warned in Elevated Tier)}}{\text{(\# EF0-1 Tornadoes)}}$

Where α and β = any numbers 0-1 representing a partially detected warned event (i.e. a warned event, but warned in the adjacent Tier);

$FCP_1 = \dfrac{\text{(\# Elevated Tier Warnings with No Tornado)} + \gamma(\text{\# Elevated Tier Warnings with EF1)} + \delta(\text{\# Elevated Tier Warnings with EF0)}}{\text{(\# Elevated Tier Warnings)}}$

$FCP_2 = \dfrac{\text{(\# Base Tier Warnings with No Tornado)} + \varepsilon(\text{\# Base Tier Warnings with EF2)} + \zeta(\text{\# Base Tier Warnings with EF3+)}}{\text{(\# Base Tier Warnings)}}$

Where γ, δ, ε, and ζ = any numbers 0-1 representing a partially verified warning (i.e. a verified warning, but in an adjacent Tier as a "near miss" (e.g. γ and ε) or a "categorical miss" (e.g. δ and ζ). See appendix A.

CCSI = Categorical Critical Success Index = $1 / ((1 / PCD) + (1 / (1- FCP)) - 1)$
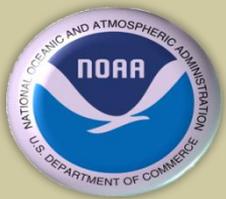
Elevated Tier ($\alpha=1$; $\gamma=0$, $\delta=0$)

90% of all EF2-5 tornadoes were warned (w/ a warning of any Tier) PCD_1
33% of all Elevated Tier Warnings ended <u>without</u> a tornado occurrence FCP_1; Hit Rate = 67%
CCSI=.62

Base Tier ($\beta=1$; $\epsilon=0$, $\zeta=0$)

49% of all EF0-1 tornadoes were warned (w/ a warning of any Tier) PCD_2
69% of all Base Tier Warnings ended <u>without</u> a tornado occurrence FCP_2 ; Hit Rate = 31%
CCSI= .23

Finding: NWS Elevated Tier Tornado Warnings are strong confidence markers of tornado occurrence (regardless of tornado magnitude).

Finding: Tornado Warning False Alarms are strongly associated with Base Tier Tornado Warnings (by volume and percentage), as compared to Elevated Tier Warnings.

Elevated Tier (α=0, γ=1, δ=1)

28% of EF2-5 Tornadoes were warned with an Elevated Tier Warning (PCD)
54% of Elevated Tier Warnings ended w/no tornado or an EF0-1 tornado (FCP)
46% Hit Rate (1-FCP); CCSI= 0.21

Base Tier (β=0, ε=1, ζ=1)

47% of EF0-1 Tornadoes were warned with a Base Tier Warning (PCD)
74% of Base Tier Warnings ended with no tornado, or an EF2-5 tornado (FCP)
26% Hit Rate (1-FCP); CCSI= 0.20

Finding: Category Hit Rate for Elevated Tier warnings is near double that of Base Tier Warnings.

Finding: While 90% of EF2-5 tornadoes are covered by some sort of Tornado warning, only 28% are covered by Elevated Tier warnings; suggesting Elevated Warnings are under-utilized.

Finding: When "near misses" and "categorical misses" are treated as false alarms and missed events, CCSI skill measures for Base Tier and Elevated Tier warnings/events are nearly identical; suggesting minimal skill distinguishing between category – particularly distinguishing EF2 from EF1 tornadoes.
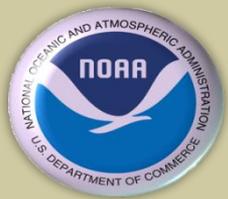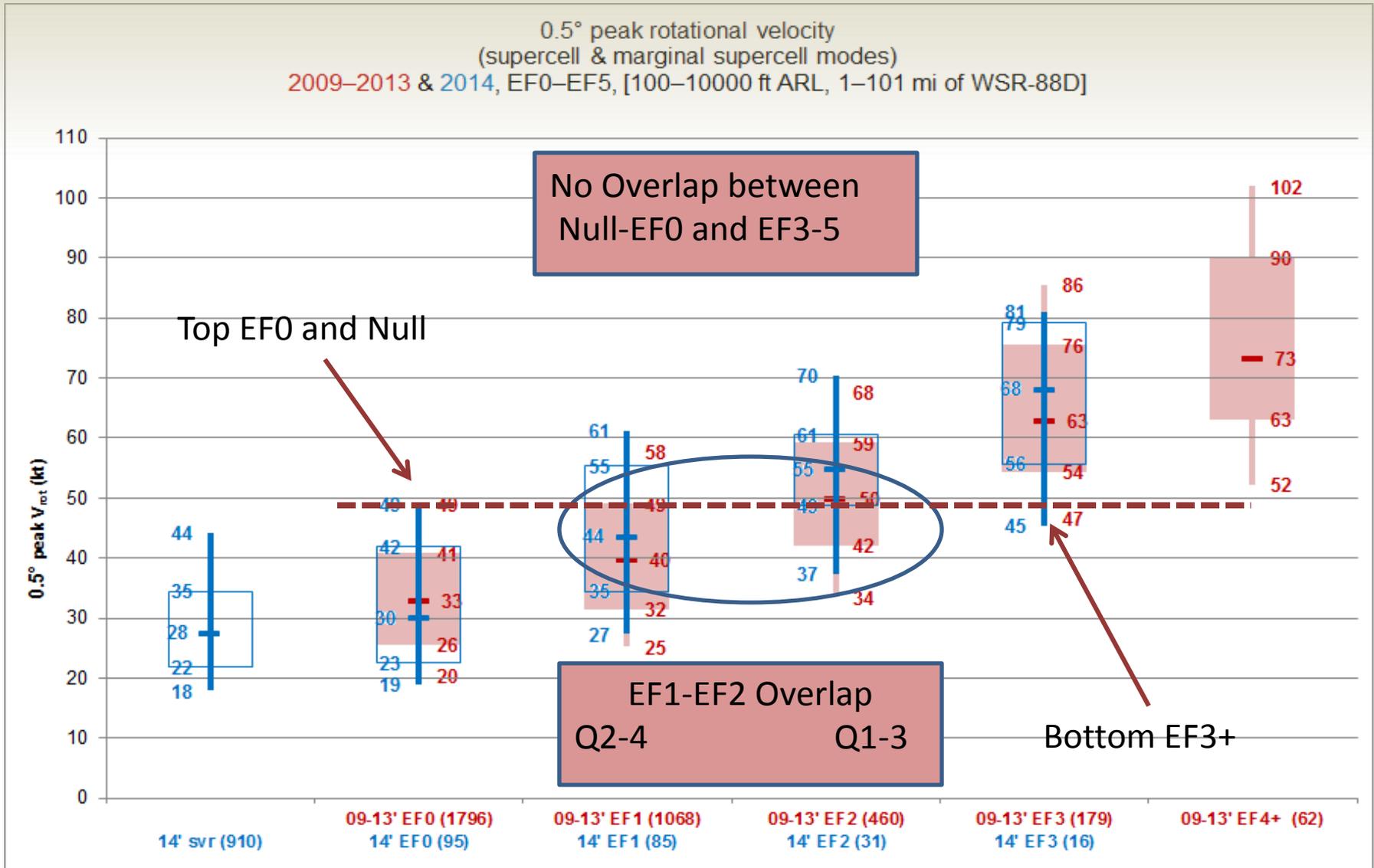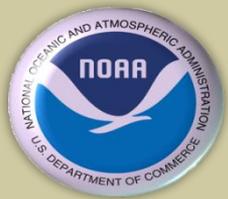
0.5° peak rotational velocity
(supercell & marginal supercell modes)
2009–2013 & 2014, EF0–EF5, [100–10000 ft ARL, 1–101 mi of WSR-88D]

Elevated Tier (α= 0.5, γ= 0.25, δ= 1)

59% of EF2-5 tornadoes warned w/ Elevated Tier (w/half credit for a Base Warning) - PCD
44% of Elevated Tier TORs ended w/ no tornado, EF0 tornado, and partial EF1 near miss - FCP
56% Hit Rate (1-FCP) – Includes partial (3/4) credit for a EF1 near miss.
CCSI= 0.40

Base Tier (β=0.5, ε= 0.25, ζ=1)

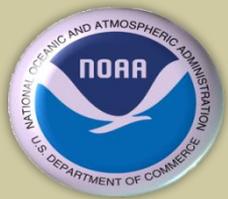48% of EF0-1 tornadoes warned w/Base Tier (w/half credit for an Elevated Warning) - PCD
72% of Base Tier TORs ended w/ no tornado, EF3+ tornado, and partial EF2 near miss - FCP
28% Hit Rate (1-FCP) – Includes partial (3/4) credit for a EF2 near miss.
CCSI= 0.21

Finding: By a substantial margin (nearly a factor of 2), CCSI skill measures for Elevated Tier Warnings/Events exceed those for Base Tier Warnings Events.

Finding: Similarly, Hit Rate for Elevated Tier Warnings exceed (by a factor of 2) Hit Rate for Base Tier Warnings.
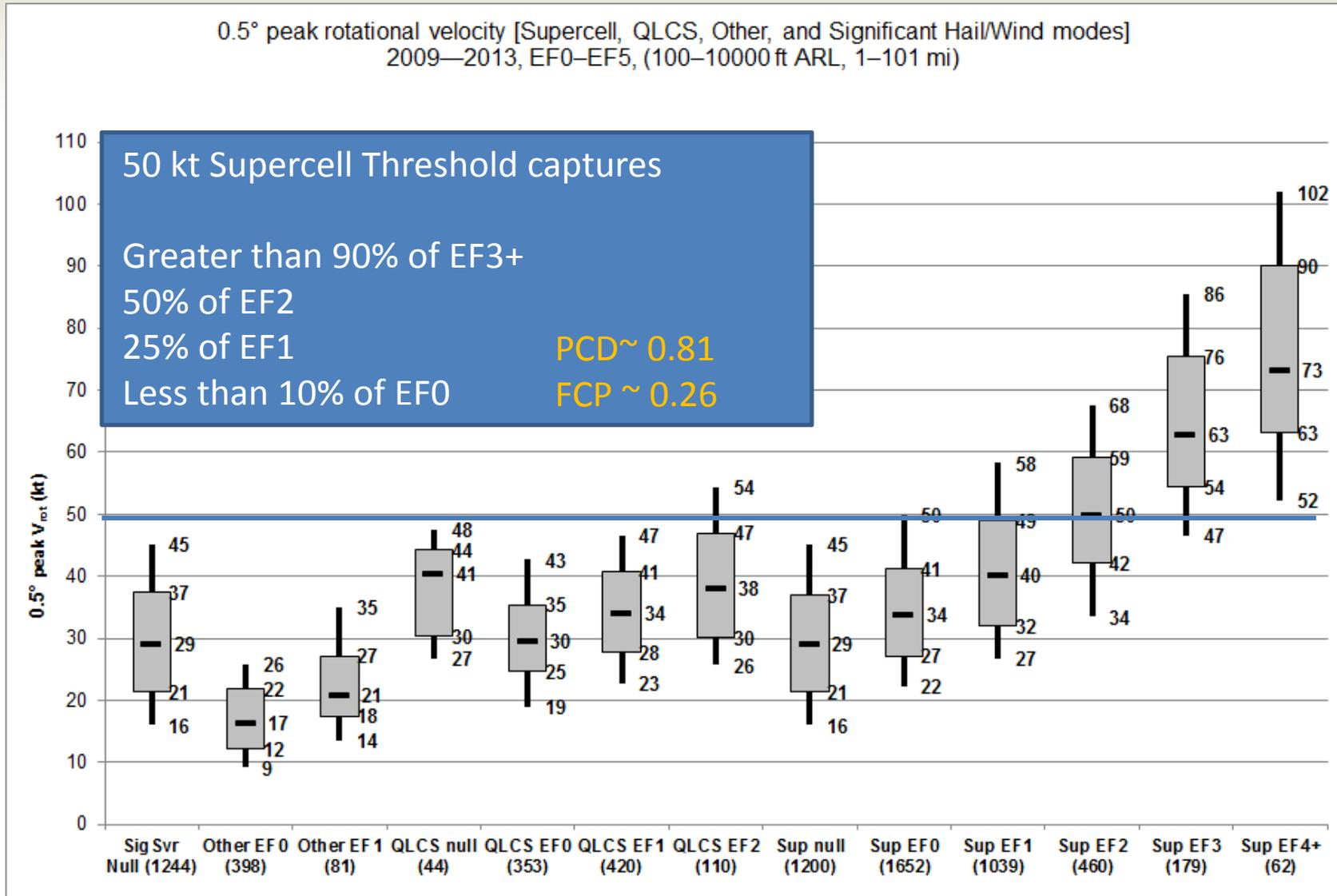
Smith et al. 2015

0.5° peak rotational velocity [Supercell, QLCS, Other, and Significant Hail/Wind modes]
2009—2013, EF0–EF5, (100–10000 ft ARL, 1–101 mi)

50 kt Supercell Threshold captures

Greater than 90% of EF3+
50% of EF2
25% of EF1   PCD~ 0.81
Less than 10% of EF0   FCP ~ 0.26

- Base Tier Warnings are dominated by false alarms (69% or worse).

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Questions ?